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CONCENTRATIONS OF SELENIUM IN SURFACE WATER, SEDIMENT AND FISH FROM THE MCLEOD, PEMBINA AND SMOKY RIVERS: RESULTS OF SURVEYS FROM FALL 1998 TO FALL 1999

INTERIM REPORT

Prepared by:

Richard Casey, M.Sc., P.Biol.

Water Sciences Branch
Water Management Division
Natural Resources Service

and

Paula Siwik, M.Sc.

Fisheries Management Division
Natural Resources Service

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1.0 INTRODUCTION

Selenium is a naturally occurring element, commonly found in rocks and soil. Natural sources of selenium include Cretaceous marine sedimentary rocks, coal and other fossil fuel deposits (CCREM 1987; US-EPA 1987; Haygarth 1994). Anthropogenic sources causes of selenium in surface waters include coal ash from coal-fired power plants, irrigation waters from seleniferous soils and wastewaters from some industrial processes (CCREM 1987; US-EPA 1987). Selenium is an essential nutrient for humans and other organisms. However, it can also be toxic to organisms, including fish and other aquatic biota, at concentrations slightly higher than nutritional levels required by biota (Lemly and Smith 1987; Maier and Knight 1994). Toxic effects of selenium on aquatic biota include mortality, deformities and reproductive failure (Lemly and Smith 1987; Maier and Knight 1994). The biogeochemistry and effects of selenium in aquatic food webs is complex and not clearly understood (Lemly and Smith 1987; Masscheleyn and Patrick 1993; Maier and Knight 1994). In aquatic systems, selenium in surface water can accumulate in sediments and lower trophic levels (e.g., algae and invertebrates) which in turn are consumed by organisms at higher trophic levels (e.g., fish). In this way, selenium at low concentrations in surface waters can bioaccumulate to higher concentrations in aquatic organisms, potentially leading to toxic effects.

Selenium mobilization related to surface coal mines in Wyoming, British Columbia and Alberta has only recently come to light in the 1990s (Dreher and Finkelman 1992; McDonald and Strosher 1998). In these cases, the actual sources of selenium are still being explored, but they appear to be associated with selenium-bearing rock and soil, and various disturbances and activities associated with surface mining. In cold, flowing waters, such as the mountain areas of Alberta and B.C., the fate and effects, if any, of elevated selenium concentrations are not yet understood.

Concerns about selenium in surface waters were expressed at the 1997 Cheviot Hearing based on the findings of elevated selenium in surface waters and fish close to coal mines in south-east British Columbia. A 1998 report on these findings showed selenium concentrations above water quality guidelines at sites downstream of surface coal mines in the Elk River system in south-east B.C (McDonald and Strosher 1998). Selenium concentrations upstream of the mines were below water quality guidelines (McDonald and Strosher 1998). In September 1998, data submitted to AENV by Cardinal River Coals Ltd., Alberta, (CRC) revealed selenium concentrations in Lac des Roches, an end pit lake at the CRC mine, which were greater than water quality guidelines. These data included occasional water samples from the lake after it began to spill in the late 1980's. The

results indicated an order of magnitude increase in selenium concentrations in 1997 and 1998, compared to 1991 to 1993. In October 1998, Alberta Environment (AENV) initiated additional sampling at Lac des Roches and other streams close to the CRC and Gregg River mines. These results confirmed the industry data for Lac des Roches. The results also showed selenium concentrations greater than water quality guidelines in other water bodies close to the mines. A review of water quality data supplied to AENV by the Inland Cement Ltd. limestone quarry at Cadomin showed no selenium concentrations above water quality guidelines in the McLeod River, at sites upstream and downstream of the quarry, during water surveys from May to August 1998.

This report includes the initial findings of a study initiated in spring 1999 by the Water Management Division and Fisheries Management Division (Natural Resources Service). The study was designed to obtain data on the concentrations of selenium in surface water, sediment and aquatic biota at about 30 sites, including areas upstream (reference sites) and downstream of four coal mines. The mines, Cardinal River Coals Ltd. (CRC), Gregg River and Coal Valley mines owned by Luscar Ltd. and Smoky River Coal Ltd., are located in the Northern East Slopes Region of AENV. Sample sites were located in the McLeod, Lovett, Pembina and Smoky river basins, and at Fairfax Lake, a reference lake, and Lac des Roches, an end pit lake at the CRC mine. The study is being conducted with the assistance of the coal mines.

The main objectives of the study are:

1. To determine concentrations of selenium in surface waters and aquatic sediments in streams and lakes of the Gregg River, McLeod River, Lovett River and Smoky River systems.
2. To document and assess selenium concentrations in fish and other aquatic biota at some of these locations.

2.0 SCOPE OF REPORT

This report provides a compilation of findings to date. The data include surface water and fish tissue concentrations from samples collected in spring, summer and fall surveys, and sediment data for two lakes collected in spring and summer. In addition to these data, sediment and other biota (aquatic invertebrates, biofilm and aquatic plants) were sampled at flowing-water sites in the fall, 1999. A final survey of water will be conducted in winter 2000. Data from all samples will be presented in a final report that will be prepared after all data are validated and analysed.

Additional selenium data available from the separate McLeod River Water Quality Study (1998-2000) are also included in this report.

3.0 STUDY APPROACH AND METHODS

3.1 OBJECTIVE 1

Collection of samples was initiated in May 1999 to obtain seasonal data for selenium in surface waters and sediments of headwater streams, mainstem sites and lakes of the Gregg, McLeod, Pembina (primarily Lovett River) and Smoky River basins (Figures 1 and 2; Table 1).

At most sites, grab samples of the surface water were taken once during spring, summer and fall. Some additional sites were added to the study as it progressed. Samples will also be taken at most sites during winter 2000. At each flowing-water site, a grab sample of water was taken in a well-mixed zone. A composite sample of the upper 1-2 cm of sediment was taken in depositional areas. Sampling of sediment was restricted to the fall during low flow conditions when sediment was more accessible. At Lac des Roches and Fairfax Lake, water and sediment samples were taken in spring and summer. At each lake, a composite sample of the upper water column was taken at several points ($\geq$6 sites) around the lake and a composite sample of cores of the upper 3-5 cm of sediment was taken from the littoral area. At Lac des Roches (maximum depth >100 m) discrete water samples were also taken at various depths throughout the water column.

Conductivity, pH, dissolved oxygen and temperature were measured using field meters at all sites; profiles of these parameters were taken in the lakes. Instantaneous discharge was measured at the most downstream site of selected streams (Luscar, Berry's, Falls and Beaverdam creeks).

3.2 OBJECTIVE 2

Fish collections focussed on rainbow trout, a spring spawner, at a sub-set of the McLeod River basin sites used in Objective 1 (Table 1). In addition, egg samples were collected from bull trout in Mackenzie Creek.

Fish samples were collected with different gear: a Smith-Root type VII backpack electrofisher on Whitehorse and Luscar Creeks; a boat (14 foot Avon raft) equipped with a Smith-Root type 5.0 GPP electrofishing unit on the McLeod and Gregg River mainstem sites; and gill nets in Fairfax Lake. Bull trout were captured in Mackenzie Creek by angling. Whenever possible,

mature gravid females were taken for tissue samples. Skeletal muscle and egg samples from rainbow trout were collected in late May to early June, 1999. The fish were placed on ice immediately following field collection and transported to the laboratory where measurements of fork length and weight were taken. Each specimen was classified for sexual maturity, and otoliths and scales were removed to determine the age of the fish. Tissue samples from the fish were removed using a high carbon steel knife and forceps. Individual fillets and ovaries/eggs were removed, placed in individual whirlpack bags, labeled and frozen immediately. The samples were kept frozen until they were analysed. Eggs from seven bull trout were collected from mature gravid females in Mackenzie Creek during September, 1999. At this time bull trout migrate up Mackenzie Creek from the McLeod River to spawn. Egg samples were stripped from females into whirlpack bags in the field, labeled, placed on ice and then frozen until they were analysed. Field measurements of bull trout included total length and classification of sexual maturity. All fish were collected under direct supervision of Fisheries Management staff (NES Region), except for the fish from Lac des Roches which were taken by Pisces Environmental Consulting Services Ltd.

In addition to fish, benthic macroinvertebrates, biofilm and aquatic plants were sampled at some McLeod River and Gregg River sites during early October (Table 1). Benthic macroinvertebrates (mostly Ephemeroptera, Trichoptera, Plecoptera and Chironomidae) were sampled at two sites using kick-net sampling techniques. The organisms were extracted from the sample net with Teflon-covered forceps. Biofilm, the community of algae and other organisms attached to the top of rocks, was sampled at nine sites by scraping samples from several rocks at each site using a plastic knife. Aquatic vegetation (*Potamogeton* sp., aquatic moss and an emergent aquatic plant) were collected at three sites. All samples were frozen immediately using dry ice and kept frozen until the samples were analysed. The samples were collected by the Monitoring Branch, Water Management Division, AENV.

3.3 ANALYSIS OF SAMPLES AND QUALITY ASSURANCE

Analysis of selenium and total suspended sediment (TSS) was conducted at the Alberta Research Council (ARC), Vegreville. Water samples were analysed for total recoverable and dissolved selenium, and TSS. Sediment and biological samples were analysed for total selenium (acid extraction). Selenium was measured using inductively coupled plasma mass spectrometry (ICP-MS). The detection limits were 0.5 μg/L in water and $\leq$0.5 μg/g in sediment and biological

tissues. Total organic carbon and size fractions of the sediment samples were analysed by Maxxam Analytics Ltd., Calgary. Samples for quality assurance (triplicate-split and field blank water samples) were included in the field program. Additional quality assurance, including the analysis of spiked samples and replicates of water, sediment and biological samples, was carried out at the ARC laboratory.

4.0 UPDATE TO WATER QUALITY GUIDELINES USED IN ALBERTA

Currently, the Canadian Council of Ministers of the Environment (CCME) and the U.S. Environmental Protection Agency (US-EPA) guidelines are being used as general guidance for evaluating surface water quality for the protection of freshwater aquatic life in Alberta (AENV 1999).

- The CCME surface water guideline is 1 µg/L total selenium. This guideline is listed in the CCME Priority List (1998-99) for review and possible revision.
- The US-EPA surface water guideline was recently revised and released in April 1999. The 1999 revision did not affect the guideline for chronic effects (5 µg/L total recoverable selenium). The acute guideline was revised from 20 µg/L total recoverable selenium to a calculated value based on the concentrations of two fractions of total selenium, selenite and selenate, which are known to be toxic to aquatic life. These chemical forms of selenium are not presently measured in routine monitoring in Alberta.
- The old interim Alberta guideline of 10 µg/L total selenium (AEP 1993), originally designated in 1977, is no longer being used by the province (AENV 1999).

5.0 RESULTS AND DISCUSSION

5.1 QUALITY ASSURANCE

The analytical results for blank and triplicate-split samples taken in the field, and the spiked and replicate samples analysed in the laboratory are compiled in Appendix 1. The results indicate the accuracy and precision of the selenium data in this project were well within those regularly achieved by AENV monitoring, and are considered satisfactory.

5.2 SELENIUM STUDY 1999-2000

5.2.1 Surface Waters

Total recoverable selenium concentrations at 11 reference (background) sites ranged from <0.5 to 2.2 µg/L (Table 2). Three out of the 32 samples (9.4%) at the reference sites were greater than the CCME guideline of 1 µg/L (Table 2). The remaining 21 sites in the study were downstream of active coal mines and the limestone quarry at Cadomin (Table 2). The highest concentrations of total recoverable selenium, up to a maximum of 47.1 µg/L and all more than the US-EPA chronic guideline of 5 µg/L, were found in Luscar, Berry's, Falls, Sphinx and Beaverdam creeks, Gregg River and Lac des Roches (Table 2). These sites were downstream of the CRC, Gregg River and Smoky River mines (Figures 1 and 2).

In most streams where there were sample sites at an upstream reference area and downstream of mine disturbances, there was an increase of selenium concentrations in each season at the downstream site. These streams were Luscar Creek, Berry's Creek, Sphinx Creek, Gregg River, and Beaverdam Creek (Table 2). In Sheep Creek and Lovett River, there were small increases, decreases, or no change in the concentrations of selenium between sites upstream and downstream of the Smoky River and Coal Valley mines, respectively (Table 2). Selenium concentrations in the Muskeg River near the mouth were less than or close to the detection level (0.5 µg/L)(Table 2). This site was downstream of the Flood Creek fly ash disposal site which contains fly ash, bottom ash and reject material from the coal-fired power plant beside the Smoky River mine.

Evaluation of seasonal patterns in the concentrations of selenium at the flowing-water sites will be conducted after completion of sampling in winter 2000. However, at most sites where selenium concentrations were greater than 1 µg/L, the lowest concentrations often occurred in the spring, compared to the summer and fall (Table 2). The lower concentrations in spring may have been caused by dilution from higher runoff and flows. Concentrations of TSS were greater in spring than in summer and fall; average TSS concentrations were 28, 5 and 1 mg/L, respectively. The higher TSS concentrations in spring were likely caused by higher runoff and flows. Therefore, selenium concentrations did not appear to be affected by TSS in the water column. Preliminary data from ARC indicate that in spring, summer and fall 1999, the selenium in water samples was almost entirely in the dissolved form.

5.2.2 Sediment in Lakes

In spring and summer, 1999, sediments were sampled from the littoral zone (<2 m depth) of Fairfax Lake and Lac des Roches. Selenium concentrations in all samples from Lac des Roches were greater than in Fairfax Lake (Table 3).

5.2.3 Rainbow Trout Tissues

The following summarises data for rainbow trout (*Oncorhynchus mykiss*) collected from two mainstem sites and four tributaries of the McLeod River, and two lakes in spring 1999 (Table 1). Most fish were females (85%) and even though all fish were of different ages and stages of maturity, patterns in concentrations of selenium in fish tissues were found (Tables 4 and 5).

Selenium concentrations in rainbow trout ranged from 0.13 to 9.34 µg/g wet weight in muscle and from 0.02 to 28.90 µg/g wet weight in eggs at all sites (Tables 4 and 5). For 42 out of 43 fish, there was a greater concentration of selenium in eggs compared to muscle from the same fish (Tables 4 and 5). Selenium concentrations in muscle and eggs showed a strong positive relationship ($r^2 = 0.72$, $p<0.01$, regression analysis).

With few exceptions, the lowest concentrations of selenium in muscle and eggs were found at the reference sites, Wampus Creek, Whitehorse Creek and Fairfax Lake, compared to the remaining sites downstream of mines (Tables 4 and 5; Figure 3). At Whitehorse Creek, the concentration of selenium in the eggs of three of five females were at least an order of magnitude greater than egg concentrations in the remaining fish from the other reference sites (Table 7). These high egg concentrations may have been caused by migratory movements of the fish from areas with elevated selenium concentrations in the water and food. For example, there is evidence that rainbow trout in the McLeod River will migrate into the lower reaches of some of the larger tributaries, and that rainbow trout in small tributaries, such as Wampus Creek, are mostly resident (Sterling 1980).

Greatest mean concentrations of selenium in both muscle and egg tissues were found at the two sites close to the CRC mine, Lac des Roches and Luscar Creek (Figure 3). At the three remaining sites downstream of the CRC and Gregg River mines, greatest mean selenium concentrations in tissues were in the Gregg River and McLeod River, in a 1.5 km reach, immediately downstream of the confluence with the Gregg River (Figure 3).

Mean selenium concentrations in rainbow trout muscle and eggs showed a positive correlation with selenium concentrations in water samples taken about the same time (muscle:

r=0.88, p<0.08; eggs: r=0.85, p<0.02; Figures 4 and 5). Fish results from the McLeod River site downstream of the Gregg River were not included in this analysis because a water sample was not taken at the site.

5.3 MCLEOD RIVER WATER QUALITY STUDY 1998 - 2000

Additional selenium data were sampled at up to 14 sites in five seasonal surveys from September 1998 to September 1999 (Table 6). The sites were six McLeod River locations from upstream of Cadomin to Whitecourt, two major tributaries (Gregg and Embarras rivers) and small streams (Jarvis, Luscar, Berry's, Falls and Sphinx creeks) in the McLeod River and upper Gregg River (Table 6).

Selenium concentrations at the reference site, McLeod River upstream of Cadomin Creek, ranged from 0.5 to 1.3 µg/L total recoverable selenium; one of five samples was greater than the CCME water quality guideline of 1 µg/L (Table 6). The greatest selenium concentrations were consistently found in all of the small streams sampled at sites downstream of the CRC and Gregg River mines. Many of these selenium concentrations were greater than the CCME and US-EPA chronic (5 µg/L) water quality guidelines (Table 6; Figure 6). Concentrations ranged up to a maximum of 36.3 µg/L total recoverable selenium. These findings were similar to the data collected in many of the same streams during the Selenium Study (Section 5.2.1).

In the McLeod River, the highest concentrations generally occurred at the first site downstream of Luscar Creek, i.e., McLeod River upstream of the confluence with Gregg River (Table 6). Selenium concentrations then decreased in a downstream direction to concentrations below the detection level (≤0.5 µg/L) at Whitecourt (Table 6). Selenium concentrations at sites upstream of Edson (excluding the most upstream reference site) were often close to or greater than the CCME water quality guideline, but always less than the US-EPA guideline (Table 6; Figure 6). In the Gregg River, 8 km upstream of the confluence with the McLeod River, selenium concentrations ranged from 1.2 to 3.4 µg/L total recoverable selenium (Table 6; Figure 6). Concentrations in the Embarras River were always less than the detection level (Table 6; Figure 6).

6.0 SUMMARY OF FINDINGS

Data from all surveys showed low concentrations of selenium in water at reference sites, relative to sites downstream of the CRC, Gregg River and SRC mines. Most of these concentrations

(86%) were less than the CCME water quality guideline for the protection of freshwater aquatic life. Concentrations in several small streams downstream of coal mines were often an order of magnitude greater than both the CCME and US-EPA chronic guidelines currently used in Alberta. These streams included Luscar, Berry's, Falls, Sphinx and Beaverdam creeks. Similar high concentrations of selenium were also found in Lac des Roches and Jarvis Creek downstream of the lake. Almost all of the selenium in the water samples appeared to be in the dissolved form. Selenium concentrations in samples of littoral sediments were always higher in Lac des Roches than in the reference lake, Fairfax Lake.

Selenium concentrations in rainbow trout ranged from 0.13 to 9.34 µg/g wet weight in muscle and from 0.02 to 28.90 µg/g wet weight in eggs. Selenium in eggs was positively related to selenium in muscle tissues. With few exceptions, the lowest concentrations of selenium in muscle and eggs were found at the reference sites, Wampus Creek, Whitehorse Creek and Fairfax Lake, compared to the remaining sites downstream of mines. Greatest mean concentrations of selenium in both muscle and egg tissues were found at the two sites close to the CRC mine, Lac des Roches and Luscar Creek. Mean selenium concentrations in rainbow trout muscle and eggs showed a positive correlation with selenium concentrations in water samples taken about the same time.

7.0 REFERENCES

AENV. 1999. Surface water quality guidelines for use in Alberta. Environmental Sciences Division and Water Management Division, Alberta Environment, Edmonton, Alberta. 20 p. This document is available at the AENV website: http://www.gov.ab.ca/env/water/reports.

AEP. 1993. Alberta ambient surface water quality interim guidelines. Standards and Guidelines Branch, Alberta Environmental Protection, Edmonton, Alberta. 4 p.

CCREM. 1987. Canadian water quality guidelines. Canadian Council of Ministers of Resources and Environment. Ottawa, Ontario.

CCME. 1999. Canadian environmental quality guidelines. Canadian Council of Ministers of Environment. Environment Canada, Hull Quebec.

Dreher, G.B., and R.B. Finkelman. 1992. Selenium mobilization in a surface coal mine, Powder River basin, Wyoming, U.S.A. Environ. Geol. Water Sci. 19: 155-167

Haygarth, P.M. 1994. Global importance and global cycling of selenium. Pages 1-28 in *Selenium in the environment*. Edited by W.T. Frankenberger, Jr. and S. Benson. Marcel Dekker, Inc. New York.

Lemly, A.D., and G.J. Smith. 1987. Aquatic cycling of selenium: implications for fish and wildlife. United States Department of the Interior, Fish and Wildlife Service. Washington, D.C. 10 p.

Maier, K.J., and A.W. Knight. 1994. Ecotoxicology of selenium in freshwater systems. Reviews of Environmental Contamination and Toxicology 134: 31-48.

Masscheleyn, P.H., and W.H. Patrick. 1993. Biogeochemical processes affecting selenium cycling in wetlands. Environmental Toxicology and Chemistry 12: 2235-2243.

McDonald, L.E., and M.M. Strosher. 1998. Selenium mobilization from surface coal mining in the Elk River basin, British Columbia: a survey of water, sediment and biota. Ministry of Environment, Lands and Parks. Cranbrook, British Columbia. 56 p.

Sterling, G. 1980. Migratory behaviour of the major salmonid fishes, rainbow trout, dolly varden char and mountain whitefish in the Tri-Creek Watershed, 1969 to 1978. Tri-Creek Research, Report 6. Alberta Energy and Natural Resources. 63 p.

US-EPA. 1987. Ambient water quality criteria for selenium. EPA Criteria and Standards Division. EPA/440/5-87/006. 130 p.

US-EPA. 1999. National recommended water quality criteria – Correction. Office of Water 4304, United States Environmental Protection Agency. EPA 822-Z-99-001.

8.0 TABLES

Table 1. Study sites and type of sample taken in each season of the Selenium Study in the Northern East Slopes Region (AENV), 1999. Winter sampling is anticipated in February 2000.

Sample Site	Type of Site	Type of Sample and Sample Date (W=water, FT=fish tissues, S=sediment, B=biofilm, M=macroinvertebrates, V=aquatic vegetation)			
		Spring 1999	Summer 1999	Fall 1999	Winter 2000
McLeod River Basin					
Whitehorse Creek near mouth	Reference	W,FT	W	W,S	W
McLeod River upstream of Cadomin Creek	Reference	W	W	W,S,B,M	W
Luscar Creek upstream of CRC Mine	Reference	W	W	W,S	W
Luscar Creek near mouth (d/s of Lac des Roches & CRC Mine)		W,FT	W	W,S,B,M,V	W
McLeod River 3.5 km downstream of Luscar Creek		W,FT	W	W,S,B	W
Mackenzie Creek		----	----	FT	----
Upper Wampus Creek	Reference	FT	----	----	----
Wampus Creek near mouth	Reference	W	W	W,S	W
Mary Gregg Creek near mouth		----	W	W,S	W
McLeod River upstream of Gregg River		W	W	W,S,B	W
McLeod River downstream of Gregg River		FT	----	B	----
McLeod River upstream of Embarras River		W	W	W,S	W
McLeod River at Peers		----	----	B,V	----
Gregg River Basin					
Gregg River upstream of CRC Mine	Reference	W	W	W,S,B,V	W
Berry's Creek upstream of GRM	Reference	W	W	W,S	W
Berry's Creek near mouth (d/s of rock drains, waste rock dumps & ponds)		W	W	W,S	W
Falls Creek at mouth (d/s of rock drain, waste rock dump & ponds)		W	W	W,S	W
Sphinx Creek upstream of GRM	Reference	W	W	W,S	W
Sphinx Creek at mouth (d/s of GRM & CRC Mine)		W	W	W,S	W
Drinnan Creek near mouth		----	W	W,S	W
Gregg River d/s of Drinnan Creek & Warden Creek		W	W	W,S,B	W
Gregg River 8 km upstream of McLeod River		W,FT	W	W,S,B	W
Smoky River Basin					
South tributary of Beaverdam Creek, upstream of SRC Mine	Reference	----	----	W,S	W
West tributary of Beaverdam Creek (d/s of exploration roads)		W	W	W	W
South-west tributary of Beaverdam Creek (d/s of B2 dump, forest clearing)		W	W	W,S	W
Beaverdam Creek 2 km downstream of 12S-5 Pond (d/s of B1 Pit)		----	----	W,S	W
West Beaverdam Creek upstream of Beaverdam Creek	Reference	----	W	W,S	W
Beaverdam Creek 1 km downstream of West Beaverdam Creek		----	----	W,S	W
Beaverdam Creek near Mouth		W	W	----	----
Sheep Creek upstream of SRC Mine	Reference	W	W	W,S	W
Sheep Creek near mouth		W	W	W,S	W
Muskeg River near mouth, d/s of Flood Creek coal ash disposal site		----	W	W,S	W
Lovett River					
Lovett River at Hwy 40	Reference	W	W	W,S	W
Lovett River near Mouth		W	W	W,S	W
Lakes					
Fairfax Lake	Reference	W,S,FT	W,S	----	----
Mary Gregg Lake		----	W	----	----
Lac des Roches		W,S,FT	W,S	----	----

---- = no sample taken

Table 2. Concentrations of selenium in surface waters at sites close to active coal mines in the Northern East Slopes Region (AENV), 1999. Concentrations greater than the CCME guideline of 1 µg/L are shown in bold, and concentrations of selenium greater than the US-EPA chronic guideline of 5 µg/L are shaded.

Sample Site 1999	Type of Site	Selenium Concentration (total recoverable) (µg/L)		
		Spring 19-21 May	Summer 27-30 July	Fall 4-7 Oct
McLeod River Basin				
Whitehorse Creek near mouth	Reference	1.0	0.6	0.8
McLeod River upstream of Cadomin Creek	Reference	0.8	0.7	0.7
Luscar Creek upstream of CRC Mine	Reference	0.6	**2.2**	**2.2**
Luscar Creek near mouth (d/s of Lac des Roches & CRC Mine)		**5.9**	**32.0**	**27.3**
McLeod River 3.5 km downstream of Luscar Creek		**2.0**	**4.2**	**6.0**
Wampus Creek near mouth	Reference	<0.5 *	<0.5	<0.5
Mary Gregg Creek near mouth		----	**2.5**	**2.7**
McLeod River upstream of Gregg River		<0.5	**1.6**	**1.8**
McLeod River upstream of Embarras River		0.5	**1.6**	**1.7**
Gregg River Basin				
Gregg River upstream of CRC Mine	Reference	0.5	0.5	0.8
Berry's Creek upstream of GRM	Reference	1.0	0.9	0.7
Berry's Creek near mouth (d/s of rock drains, waste rock dumps & ponds)		**18.8**	**10.4**	**12.7**
Falls Creek at mouth (d/s of rock drain, waste rock dump & ponds)		**21.3**	**47.1**	**29.2**
Sphinx Creek upstream of GRM	Reference	<0.5	0.5	0.8
Sphinx Creek at mouth (d/s of GRM & CRC Mine)		**2.7**	**5.2**	**3.6**
Drinnan Creek near mouth		----	0.6	<0.5
Gregg River d/s of Drinnan Creek & Warden Creek		**1.8**	**5.4**	**4.6**
Gregg River 8 km upstream of McLeod River		**1.4**	**4.4**	**3.2**
Smoky River Basin				
South tributary of Beaverdam Creek, upstream of SRC Mine	Reference	----	----	<0.5
West tributary of Beaverdam Creek (d/s of exploration roads)		**2.4**	**1.4**	**2.1**
South-west tributary of Beaverdam Creek (d/s of B2 dump, forest clearing)		<0.5	**1.8**	0.6
Beaverdam Creek 2 km downstream of 12S-5 Pond (d/s of B1 Pit)		----	----	**15.7**
West Beaverdam Creek upstream of Beaverdam Creek	Reference	----	0.6	<0.5
Beaverdam Creek 1 km downstream of West Beaverdam Creek		----	----	**4.5**
Beaverdam Creek near Mouth		**1.2**	**4.0**	----
Sheep Creek upstream of SRC Mine	Reference	0.7	<0.5	0.9
Sheep Creek near mouth		1.0	<0.5	**1.2**
Muskeg River near mouth, d/s of Flood Creek coal ash disposal site		----	<0.5	0.6
Lovett River				
Lovett River at Hwy 40	Reference	<0.5	1.1	<0.5
Lovett River near Mouth		<0.5	<0.5	0.6
Lakes				
Fairfax Lake -euphotic composite sample	Reference	<0.5	<0.5	----
Mary Gregg Lake - grab sample		----	**1.6**	----
Lac des Roches - composite (0-30 m)		**24.4**	**27.6**	----
Lac des Roches - profile (0.1 to 90 m; max. depth = ~98 m) 0.1 m -			**48.2**	
25 m -			**19.6**	
50 m -			**13.5**	
75 m -			**22.5**	
90 m -			**35.4**	

* = sample taken 11 May
---- = no sample taken

Table 3. Concentrations of selenium in individual sediment samples taken from Fairfax Lake and Lac des Roches, 1999.

Sample Site	Selenium Concentration (µg/g, dry wt.)	
	Spring 19-21 May	Summer 27-30 July
Fairfax Lake	1.0	1.1
	0.8	<0.2
	1.1	2.2
Lac des Roches	9.4	10.5
	11.1	----
	6.0	----

---- = no sample taken

Table 4. Fish characteristics and concentrations of selenium in rainbow trout samples collected during the Selenium Study in spring 1999.

Sample Site	Type of Site	Sample ID	Sample Date	Sex and Maturity	Age	Fork Length (mm)	Weight (g wet weight)	Selenium in Muscle (µg/g wet weight)	Selenium in Egg (µg/g wet weight)
Whitehorse Ck. near Mouth	Reference	99SWE017-43	19-May-99	Ripe Female	5	225	90	0.917	4.45
Whitehorse Ck. near Mouth	Reference	99SWE017-45	19-May-99	Ripe Female	4	196	100	0.864	3.86
Whitehorse Ck. near Mouth	Reference	99SWE017-48	19-May-99	Maturing Female	3	175	60	1	11.4
Whitehorse Ck. near Mouth	Reference	99SWE017-50	19-May-99	Maturing Female	3	175	50	1.07	14.6
Whitehorse Ck. near Mouth	Reference	99SWE017-52	19-May-99	Maturing Female	3	146	30	1.24	21.2
Whitehorse Ck. near Mouth	Reference	99SWE017-41	19-May-99	Mature Male	3	194	90	0.96	
Whitehorse Ck. near Mouth	Reference	99SWE017-42	19-May-99	Mature Male	3	173	70	1.13	
Whitehorse Ck. near Mouth	Reference	99SWE017-47	19-May-99	Immature Male	3	180	60	1.23	
Whitehorse Ck. near Mouth	Reference	99SWE017-54	19-May-99	Maturing Male	3	165	50	0.91	
Whitehorse Ck. near Mouth	Reference	99SWE017-55	19-May-99	Mature Male	3	139	30	1.13	
Luscar Ck. near Mouth		99SWE017-56	17-May-99	Green Female	6	316	400	4.3	19.9
Luscar Ck. near Mouth		99SWE017-58	17-May-99	Green Female	4	269	250	3.48	16.2
Luscar Ck. near Mouth		99SWE017-60	17-May-99	Green Female	4	252	210	2.78	16.5
Luscar Ck. near Mouth		99SWE017-62	26-May-99	Immature Female	3	160	50	3	17.6
Luscar Ck. near Mouth		99SWE017-66	26-May-99	Maturing Female	3	173	60	3.33	16.5
Luscar Ck. near Mouth		99SWE017-68	26-May-99	Green Female	3	182	80	4.72	20.9
Luscar Ck. near Mouth		99SWE017-70	26-May-99	Maturing Female	3	164	40	3.32	28.9
Luscar Ck. near Mouth		99SWE017-64	26-May-99	Spent Male	3	198	90	9.34	
Luscar Ck. near Mouth		99SWE017-65	26-May-99	Ripe Male	3	159	40	3.64	
Luscar Ck. near Mouth		99SWE017-72	26-May-99	Immature Male	2	122	20	3.4	
McLeod R. d/s of Luscar Ck.		99SWE017-78	21-May-99	Green Female	4	187	70	1.04	5.55
McLeod R. d/s of Luscar Ck.		99SWE017-81	21-May-99	Immature Female	3	125	20	0.714	
McLeod R. d/s of Luscar Ck.		99SWE017-82	21-May-99	Maturing Female	4	168	40	0.497	5.97
McLeod R. d/s of Luscar Ck.		99SWE017-84	21-May-99	Maturing Female	3	145	20	0.993	5.79
McLeod R. d/s of Luscar Ck.		99SWE017-75	21-May-99	Ripe Male	3	160	170	0.97	
McLeod R. d/s of Luscar Ck.		99SWE017-80	21-May-99	Ripe Male	3	186	196	0.97	
McLeod R. d/s of Luscar Ck.		99SWE017-73	21-May-99	Immature Female	2	122	130	0.87	
McLeod R. d/s of Luscar Ck.		99SWE017-74	21-May-99	Immature Female	2	128	137	1.1	
McLeod R. d/s of Luscar Ck.		99SWE017-76	21-May-99	Immature Female	2	122	128	1.14	
McLeod R. d/s of Luscar Ck.		99SWE017-77	21-May-99	Immature Female	3	136	143	1.12	

...continued on next page

Table 4. Continued.

Sample Site	Type of Site	Sample ID	Sample Date	Sex and Maturity	Age	Fork Length (mm)	Weight (g wet weight)	Selenium in Muscle (µg/g wet weight)	Selenium in Egg (µg/g wet weight)
Wampus Ck. near Mouth	Reference	99SWE018-19	29-May-99	Ripe Female	5	176	47	0.593	0.021
Wampus Ck. near Mouth	Reference	99SWE018-21	29-May-99	Ripe Female	5	160	40	0.749	1.88
Wampus Ck. near Mouth	Reference	99SWE018-23	29-May-99	Ripe Female	5	166	43	0.521	1.37
Wampus Ck. near Mouth	Reference	99SWE018-25	29-May-99	Ripe Female	5	152	31	0.623	2.03
Wampus Ck. near Mouth	Reference	99SWE018-27	29-May-99	Ripe Female	5	160	34	0.527	1.43
Wampus Ck. near Mouth	Reference	99SWE018-29	29-May-99	Ripe Female	5	155	30	0.62	2.45
Wampus Ck. near Mouth	Reference	99SWE018-31	29-May-99	Ripe Female	6	163	36	0.677	1.97
Wampus Ck. near Mouth	Reference	99SWE018-33	29-May-99	Ripe Female	5	135	23	1.11	2.6
Wampus Ck. near Mouth	Reference	99SWE018-35	29-May-99	Ripe Female	5	165	35	0.334	1.36
Wampus Ck. near Mouth	Reference	99SWE018-37	29-May-99	Ripe Female	4	157	30	0.58	2.64
Wampus Ck. near Mouth	Reference	99SWE018-39	29-May-99	Ripe Female	5	137	21	1.04	2.65
Wampus Ck. near Mouth	Reference	99SWE018-41	29-May-99	Ripe Female	5	146	28	1.04	2.46
Wampus Ck. near Mouth	Reference	99SWE018-43	29-May-99	Ripe Female	5	169	41	0.804	2.1
Wampus Ck. near Mouth	Reference	99SWE018-45	29-May-99	Ripe Female	6	169	46	0.55	4.01
Wampus Ck. near Mouth	Reference	99SWE018-47	29-May-99	Ripe Female	5	140	26	0.829	2.89
Wampus Ck. near Mouth	Reference	99SWE018-49	29-May-99	Ripe Female	5	149	30	0.608	1.56
Gregg R. u/s of McLeod R.		99SWE017-93	20-May-99	Green Female	5	202	90	1.06	4.08
Gregg R. u/s of McLeod R.		99SWE017-95	20-May-99	Maturing Female	3	137	30	1.42	9.83
Gregg R. u/s of McLeod R.		99SWE017-97	20-May-99	Maturing Female	3	126	20	1.25	7.23
Gregg R. u/s of McLeod R.		99SWE017-99	20-May-99	Maturing Female	3	149	30	1.87	9.28
Gregg R. u/s of McLeod R.		99SWE018-01	20-May-99	Maturing Female	3	114	10	1.09	2.17
Gregg R. u/s of McLeod R.		99SWE018-03	20-May-99	Maturing Female	3	150	30	1.13	12.1
Gregg R. u/s of McLeod R.		99SWE018-05	20-May-99	Maturing Female	3	133	20	1.23	10.8
Gregg R. u/s of McLeod R.		99SWE018-07	20-May-99	Maturing Female	3	145	30	0.997	8.95
Gregg R. u/s of McLeod R.		99SWE018-09	20-May-99	Maturing Female	3	143	20	1.51	9.96
Gregg R. u/s of McLeod R.		99SWE018-11	20-May-99	Maturing Female	3	132	20	1.18	9.21
McLeod R. d/s of Gregg R.		99SWE017-86	21-May-99	Maturing Female	3	194	80	1.18	18.7
McLeod R. d/s of Gregg R.		99SWE017-90	21-May-99	Maturing Female	3	155	30	1.23	14
McLeod R. d/s of Gregg R.		99SWE017-88	21-May-99	Immature Male	3	155	80	1.62	
McLeod R. d/s of Gregg R.		99SWE017-89	21-May-99	Immature Male	2	112	30	1.54	

Table 5. Fish characteristics and concentrations of selenium in rainbow trout samples collected from Fairfax Lake and Lac Des Roches in spring 1999.

Sample Site	Type of Site	Sample ID	Sample Date	Sex and Maturity	Age	Fork Length (mm)	Weight (g wet weight)	Selenium in Muscle (µg/g wet weight)	Selenium in Egg (µg/g wet weight)
Fairfax Lake	Reference	99SWE018-13	18-May-99	Ripe Female	3	373	570	0.15	0.435
Fairfax Lake	Reference	99SWE018-15	18-May-99	Ripe Female	2	330	380	0.133	0.362
Fairfax Lake	Reference	99SWE018-17	18-May-99	Ripe Female	2	314	370	0.137	0.499
Lac Des Roches		99SWE018-59	26-May-99	Ripe Female	5	382	588	6.43	21.5
Lac Des Roches		99SWE018-61	26-May-99	Ripe Female	5	344	504	6.95	21.4
Lac Des Roches		99SWE018-63	26-May-99	Ripe Female	6	393	664	7.27	27.3
Lac Des Roches		99SWE018-65	26-May-99	Ripe Female	5	359	478	6.3	23.4
Lac Des Roches		99SWE018-67	26-May-99	Ripe Female	5	366	506	7.12	20.8
Lac Des Roches		99SWE018-69	26-May-99	Ripe Female	5	385	601	6.63	21.7
Lac Des Roches		99SWE018-71	26-May-99	Ripe Female	5	361	512	6.76	22.1
Lac Des Roches		99SWE018-73	26-May-99	Ripe Female	4	353	505	6.72	24.7
Lac Des Roches		99SWE018-75	26-May-99	Ripe Female	3	256	201	7.36	17.8
Lac Des Roches		99SWE018-77	26-May-99	Ripe Female	3	234	154	7.05	21.6
Lac Des Roches		99SWE018-79	26-May-99	Ripe Female	3	288	273	7.19	25.8
Lac Des Roches		99SWE018-81	26-May-99	Ripe Female	6	450	866	8.01	22.7
Lac Des Roches		99SWE018-83	26-May-99	Ripe Female	3	216	113	5.52	18.6
Lac Des Roches		99SWE018-85	26-May-99	Ripe Female	4	330	383	6.81	26.4
Lac Des Roches		99SWE018-87	26-May-99	Ripe Female	4	300	302	5.77	16.6
Lac Des Roches		99SWE018-89	28-May-99	Ripe Female	4	348	456	7.86	22.2
Lac Des Roches		99SWE018-91	28-May-99	Ripe Female	5	342	457	7.6	22.6
Lac Des Roches		99SWE018-93	28-May-99	Ripe Female	3	221	125	6.44	21
Lac Des Roches		99SWE018-95	28-May-99	Ripe Female	3	239	158	5.8	18.7

Table 6. Concentrations of selenium in surface waters during the McLeod River Water Quality Study in the Northern East Slopes Region (AENV), 1999. Concentrations greater than the CCME guideline of 1 µg/L are shown in bold, and concentrations of selenium greater than the US-EPA chronic guideline of 5 µg/L are shaded.

Sample Site	Selenium Concentration (total recoverable) (µg/L)							
	1998					1999		
	Fall				Winter	Spring	Summer	Fall
	Sept 1	Sept 30	Oct 19	Oct 26-27	Feb 16-17	Apr 22	June 22	Sept 16
McLeod River Basin								
McLeod R. u/s Cadomin Ck.	0.6	----	----	----	**1.3**	0.9	0.7	0.5
Jarvis Ck. u/s Luscar Ck.	----	**21.7**	**15.8**	**15.7**	**9.9**	**10.1**	----	----
Luscar Ck. u/s Jarvis Ck.	----	**23.1**	**28**	----	----	----	----	----
Luscar Ck. d/s Hwy 40 Br.	----	----	----	**18.1**	**11.2**	**9.5**	**16.7**	**34.1**
McLeod R. u/s Gregg R.	**1.2**	----	----	----	**1.4**	0.6	**1.2**	**2.9**
McLeod R. u/s Embarras R.	**1.1**	----	----	----	0.8	<0.4	1	**2.3**
Embarras R. u/s McLeod R.	<0.5	----	----	----	<0.4	<0.5	<0.5	<0.5
McLeod R. S. of Edson	0.8	----	----	----	<0.4	0.5	**1.2**	**1.4**
McLeod R. d/s Rosevear Ferry	<0.5	----	----	----	0.5	0.5	<0.5	**1.1**
McLeod R. @ Whitecourt Hwy 43 Br.	<0.5	----	----	----	<0.4	<0.4	<0.5	0.8
Gregg River Basin								
Berry's Ck. u/s Gregg R.	----	----	----	**12.4**	**15.7**	**18.7**	**3.8**	**8.9**
Falls Ck. u/s Gregg R.	----	----	----	**25.5**	**10.5**	**17.6**	**19.4**	**36.3**
Sphinx Ck. u/s Gregg R.	----	----	----	----	1	----	**2**	**3.1**
Gregg R. u/s McLeod R.	**2.9**	----	----	----	**2.2**	**1.2**	**1.4**	**3.4**

---- = no sample taken

9.0 FIGURES

Figure 1. Location of water and sediment sampling sites in the McLeod River and Pembina River basins during the Selenium Study, 1999-2000.

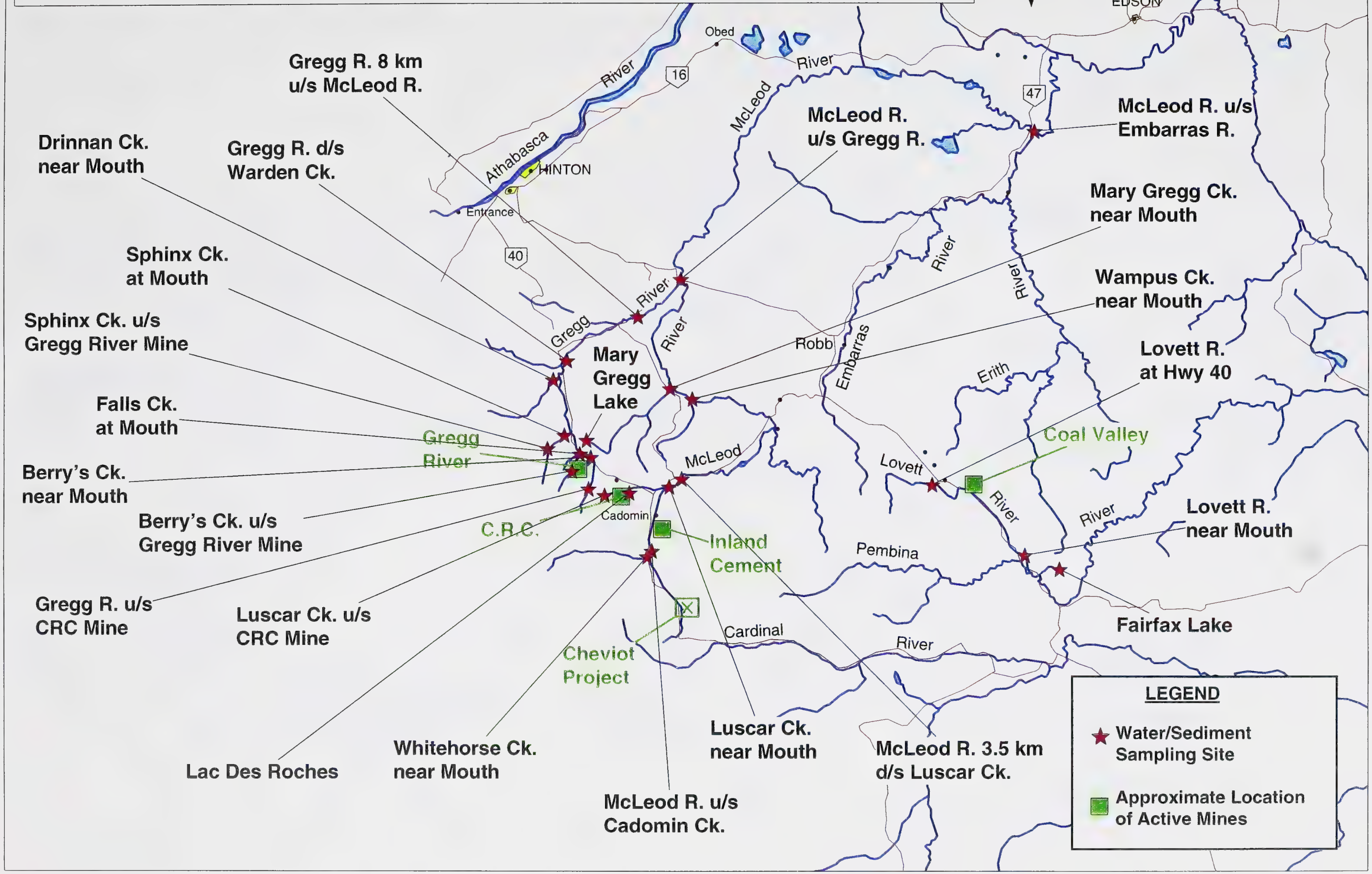
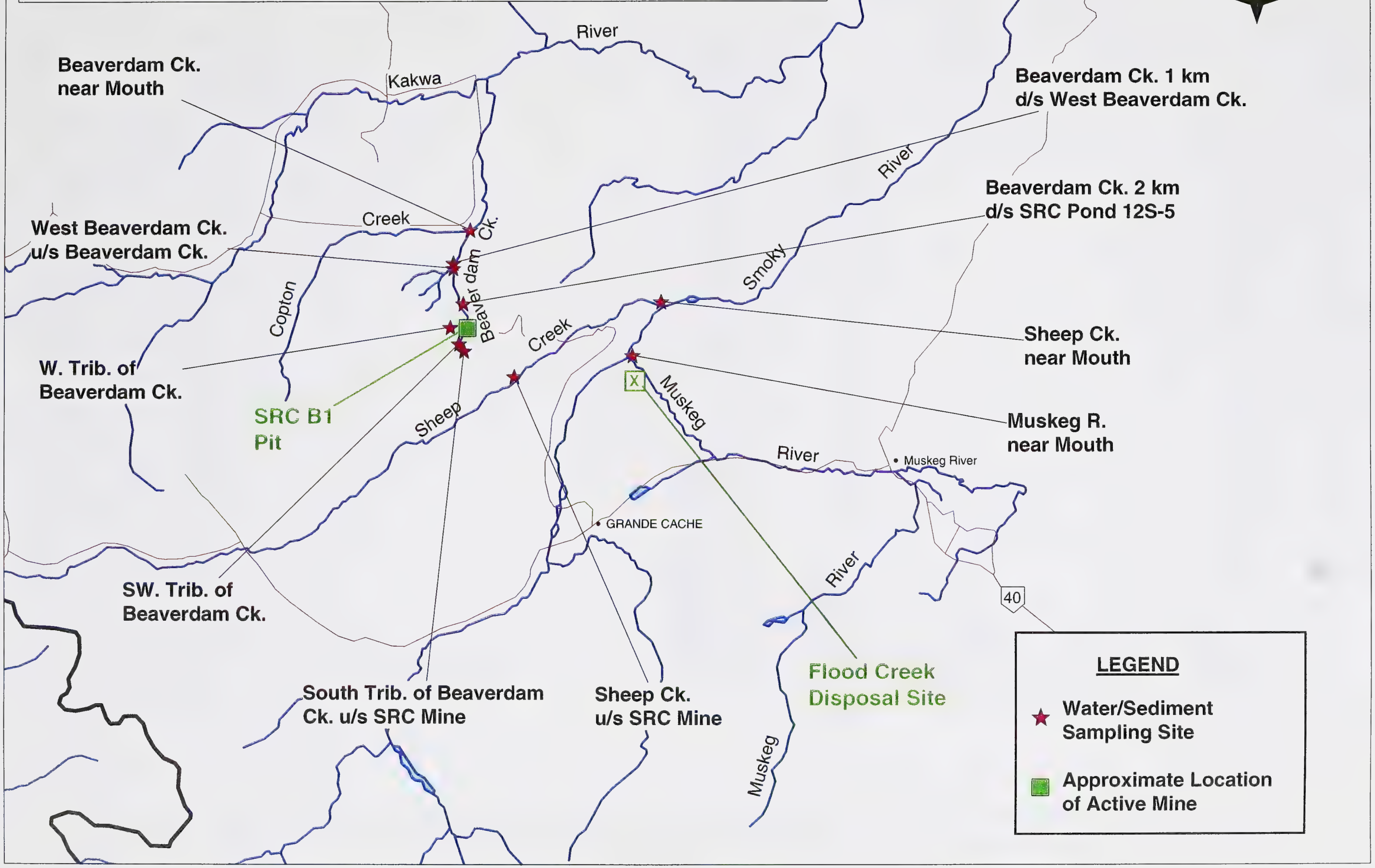


Figure 2. Location of water and sediment sampling sites in the Smoky River basin during the Selenium Study, 1999-2000.



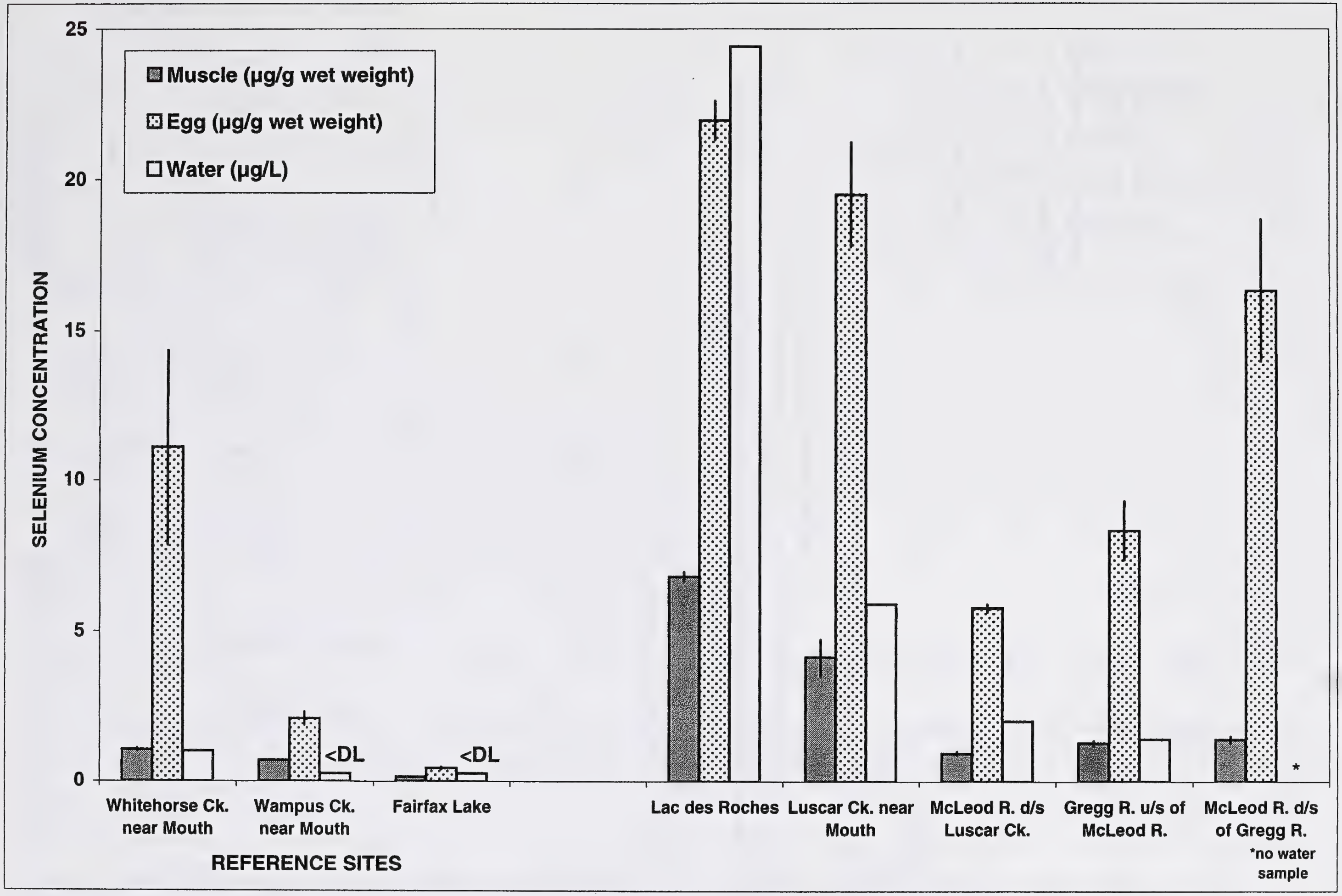


Figure 3. Concentrations of selenium in rainbow trout muscle and egg tissues (mean ± standard error), and in water in spring 1999. Selenium concentrations were less than the detection level (DL = 0.5 µg/L) in Wampus Creek and Fairfax Lake.

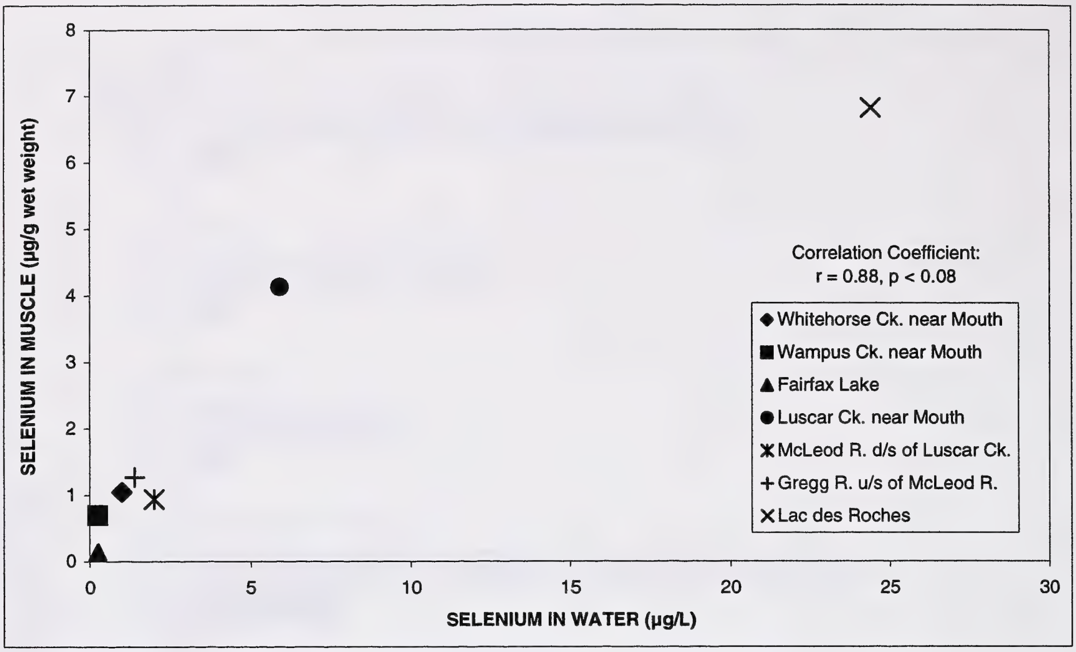


Figure 4. Concentrations of selenium in rainbow trout muscle and water in spring 1999.

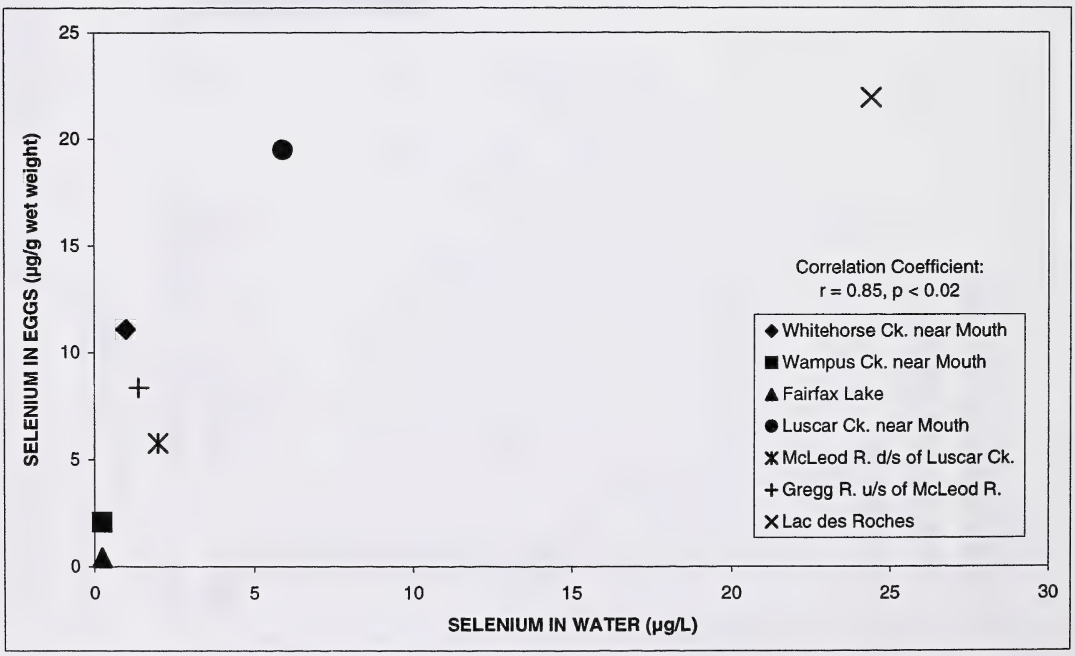


Figure 5. Concentrations of selenium in rainbow trout eggs and water in spring 1999.

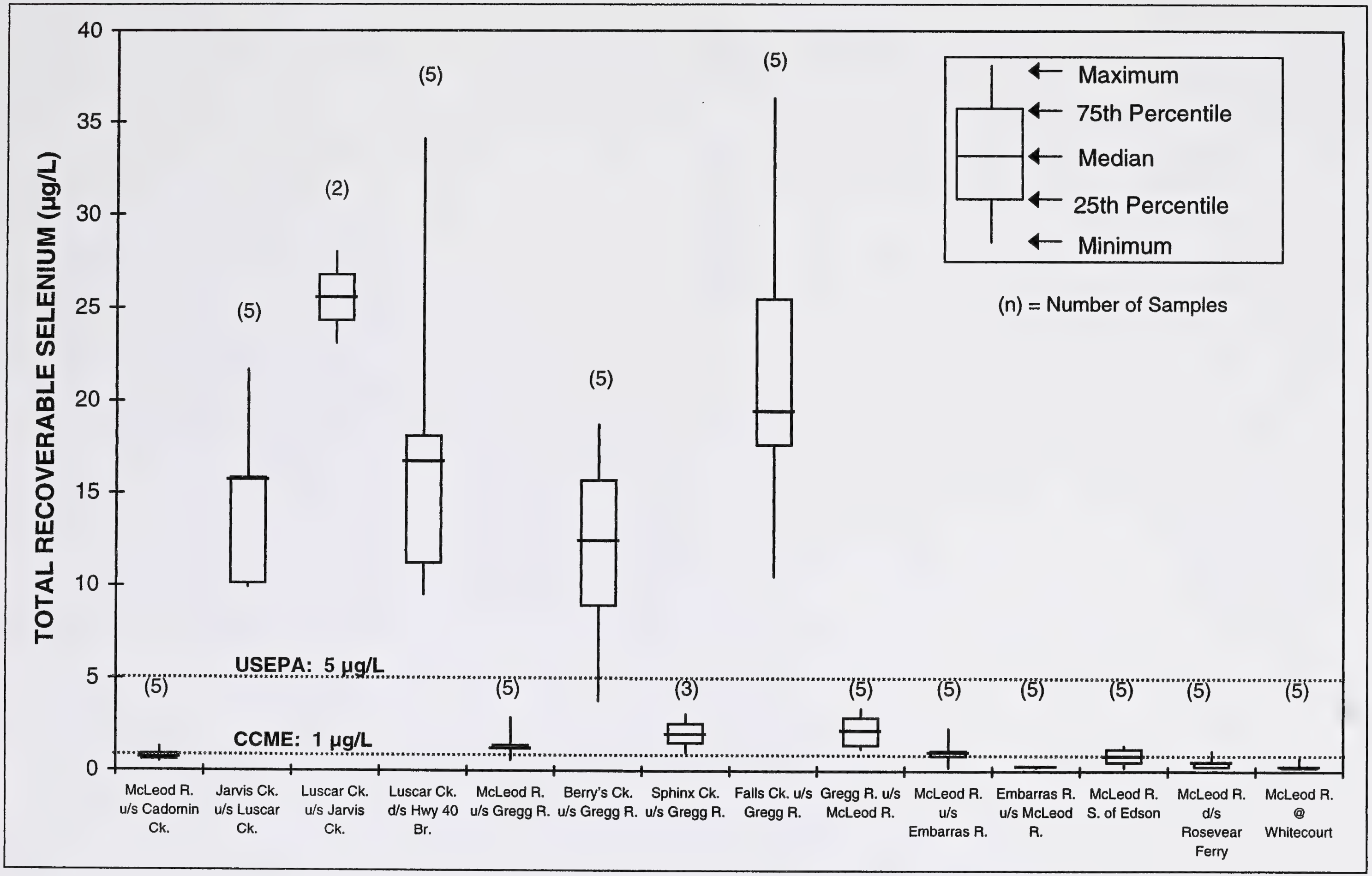


Figure 6. **Box and whisker graphs showing the concentrations of selenium at sites sampled in the McLeod River Water Quality Study from September 1998 to September 1999.**

10.0 APPENDICES

APPENDIX 1

QUALITY ASSURANCE

Quality assurance (QA) was evaluated for the Selenium Study (1999-2000) and McLeod River Water Quality Study (1998-2000) which were conducted concurrently.

No selenium was detected in any field blank water samples showing there was no measurable contamination while collecting, handling and analysing the samples (Table A1). Analytical precision was indicated by the triplicate-split results in Table A1, and ranged from 2 to 22% expressed as the coefficient of variation (CV). The CV was greater for samples with low selenium concentrations, caused by minor differences in analyses constituting a higher percentage of the mean values. These levels of precision were well within those regularly achieved by AENV monitoring programs and are considered satisfactory.

Additional work was conducted at the ARC laboratory to determine percent recoveries of selenium in single and replicate spiked samples (Table A2). The standard reference materials were from the National Institute of Standards and Technology (NIST) and Environmental Protection Agency in the U.S.A. (US-EPA), and the National Research Council in Canada (NRC) (Table A2). Percent recoveries of selenium in the reference samples of water, coal fly ash, soil and most fish tissues were similar. They were close to 100%, with a range of 20% between the lowest and highest recoveries for these media (Table A2). Percent recoveries of selenium in other biological tissues (bovine liver and wheat flour) appeared to be more variable than other biological (fish) tissues, however, only two samples in total were analysed (Table A2). Finally, when analysing the water samples taken in the first (spring 1999) survey, ARC conducted additional QA by examining the percent recoveries of selenium in samples prepared from dilutions of a standard solution of 1 mg/L selenium supplied by Seigniory Chemical Products Ltd., Quebec, Canada. Percent recoveries ranged from 101 to 104% (n=4) and 100 to 103% (n=4) in solutions of 75 and 25 μg/L selenium, respectively (Table A3).

Table A1. Quality assurance results for water samples taken during the Selenium and McLeod River Water Quality studies.

Type of Sample, Date and Site Sampled	Selenium Concentration (total recoverable) (µg/L)	Mean (µg/L)	CV (%)
Field Blanks			
30 Sep 1998	<0.5	----	----
26 Oct 1998	<0.4	----	----
27 Oct 1998	<0.4	----	----
17 Feb 1999	<0.5	----	----
22 Apr 1999	<0.5	----	----
20 May 1999	<0.5	----	----
21 May 1999	<0.5	----	----
22 Jun 1999	<0.5	----	----
27 Jul 1999	<0.5	----	----
30 Jul 1999	<0.5	----	----
16 Sep 1999	<0.5	----	----
7 Oct 1999	<0.5	----	----
Triplicate Splits			
1 Sep 1998	1.5		
McLeod R. u/s Gregg R.	1.0		
	1.1	1.2	**22**
27 Oct 1998	25.8		
Lac des Roches	25.4		
(composite 0-30 m)	25.0	25.4	**2**
17 Feb 1999	2.2		
Gregg R. u/s McLeod R.	1.9		
	2.5	2.2	**14**
5 Oct 1999	27.3		
Luscar Creek near mouth	27.4		
	26.6	27.1	**2**

CV = standard deviation as a percentage of the mean

Table A2. Percent recovery of selenium in different Standard Reference Materials (SRM).

	Recovery of Standard Reference Materials Percent Recovery ± Standard Deviation (n)							
	Water	Water	Coal Fly Ash	San Joaquin Soil	Fish Muscle	Fish Liver	Bovine Liver	Wheat Flour
Source of SRM:	NIST	US-EPA	NIST	NIST	NRC	NRC	NIST	NIST
SRM Code:	1643d	ICP-19	1633b	2709	Dolt-1	Dorm-2	1577a	1567a
Concentration of Selenium:	11.43	100 *	10.26	1.57	1.4	7.43	0.71	1.1
Units:	µg/L	µg/L	µg/g, dry wt.	µg/g, dry wt.	µg/g, dry wt.	µg/g, dry wt.	µg/g, dry wt.	µg/g, dry wt.
Spring, 1999	97.3 ± 3 (2) 95.7 ± 6 (3) 99.2 ± 3 (2)	97 ± 3 (3) 104 ± 0.3 (2) ----	99.1 ± 6 (3)	97.8 ± 11 (3)	103 ± 1 (5)	97.5 ± 6 (5)	----	----
Summer, 1999	99.3 ± 5 (3) 112 107 ± 1 (2)	102 ± .8 (3) 101 102 ± .04 (2)	90.3	90.3	99.8	118 ± 10 (2)	----	----
Fall, 1999	101 ± 1 (2) 107 ± 4 (2) 110.0	102 ± 1 (2) 103 ± .04 (2) 110.0	98.9 ± 5 (4)	106 ± 6 (2)	98.9	----	84.5	119.0

* final concentration of 100 µg/L prepared by using the US-EPA standard solution of 1.0 mg/L selenium.

---- = no sample analysed

Table A3. Percent change in concentration between replicate subsamples and readings of selenium in water, sediment and biota taken in the ARC laboratory.

Type of Sample/ Time of Survey		Sample Identification Number	Type * of Replicate	Concentration A	Concentration B	Difference Between A and B	Percent Change (%)
WATER				µg/L	µg/L		
Spring		9901752	1	0.52	0.51	0.01	2.1
		9901765	1	21.29	21.16	0.13	0.6
		9901788	1	0.97	0.97	0.00	0.3
Summer		9902819	2	1.58	1.65	-0.07	4.2
		9902843	2	15.31	14.08	1.24	8.1
		9902846	2	0.50	0.21	0.29	57.4
		9902856	2	0.60	0.31	0.29	48.6
		9902860	2	0.33	0.01	0.32	97.5
		9902866	2	1.46	1.31	0.15	10.0
		9902880	2	1.81	1.78	0.04	2.0
		9902884	2	0.07	0.81	-0.75	1115.7
SEDIMENT				µg/g dry wt.	µg/g dry wt.		
Spring		9901814	1	0.76	0.88	-0.12	16.0
		9901815	1	1.06	1.21	-0.15	14.3
		9901817	1	6.03	5.99	0.04	0.6
		9901818	1	11.14	10.11	1.03	9.2
Summer		9902823	1	2.24	1.73	0.51	22.8
		9902840	1	10.49	10.67	-0.19	1.8
Fall		9903594	1	0.64	0.67	-0.03	5.1
		9903595	1	2.20	2.08	0.12	5.6
		9903603	1	1.36	1.41	-0.05	3.8
		9903608	1	2.08	2.01	0.06	3.1
		9903609	2	1.22	1.14	0.07	6.1
AQUATIC BIOTA (fish tissues, biofilm and plant)				µg/g wet wt.	µg/g wet wt.		
	Type of Tissue						
Spring	Muscle	9902194	1	4.30	4.31	-0.01	0.2
	Muscle	9902196	1	3.48	3.57	-0.09	2.6
	Muscle	9902213	1	0.97	0.86	0.10	10.8
	Muscle	9902216	1	1.04	0.85	0.19	18.3
	Muscle	9902228	1	1.23	1.25	-0.01	0.9
	Muscle	9902251	1	0.15	0.17	-0.02	15.3
	Muscle	9902275	1	0.58	0.58	0.00	0.5
	Muscle	9902289	1	4.40	4.27	0.13	3.0
	Muscle	9902297	1	6.43	6.57	-0.14	2.2
	Muscle	9902301	1	7.27	7.30	-0.03	0.4
	Muscle	9902319	1	8.01	8.72	-0.71	8.8
	Eggs	9902254	1	0.36	0.32	0.04	11.5
	Eggs	9902290	1	16.67	15.96	0.71	4.3
Summer	Eggs	9903140	1	4.69	5.41	-0.72	15.5
	Eggs	9903140	2	4.69	5.31	-0.62	13.3
Fall	Eggs	9903856	1	4.76	5.02	-0.26	5.5
	Eggs	9903857	1	4.19	4.37	-0.17	4.1
				µg/g dry wt.	µg/g dry wt.		
	Biofilm	9903865	1	1.24	1.25	-0.01	1.0
	Aquatic Plant	9903872	1	16.95	17.38	-0.43	2.5

* 1 = two subsamples of the same sample; 2 = two readings of the same sample

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